Chapter 6

Assessment of toothing schemes in CBM wall

6.1 General Discussion

A typical confined brick masonry (CBM) wall consists of in-situ cast reinforced concrete (RC) vertical and horizontal elements that enclose unreinforced masonry (URM) wall segments. Once the masonry wall is erected, concrete is poured into these RC tie-columns and tie-beams, filling any voids and encasing the vertically protruding reinforcement bars that extend from the foundation. This process creates a composite structure where the bond between the concrete tie elements and the masonry plays a pivotal role in determining the wall's performance under lateral loads, such as those caused by seismic forces.

The strength of this bond, which is primarily dependent on the interaction between the concrete and the masonry, is influenced by several factors, including concrete shrinkage. Shrinkage can reduce the effectiveness of the bond, potentially leading to weakened structural behaviour. Therefore, ensuring a strong and durable connection between the masonry walls and the adjacent RC tie-columns is crucial for enhancing the seismic performance of CBM walls. A robust bond helps to prevent issues like premature cracking and the detachment of masonry from its confining RC elements, which can severely compromise the wall's ability to withstand seismic forces.

Optimising this bond not only improves the overall strength and stability of CBM structures but also plays a vital role in preventing structural failures during seismic events. Thus, careful attention to the quality of the connection between masonry and RC tie-columns is essential for achieving resilient and safe masonry walls in seismic-prone areas.

Previous experimental tests and earthquake damage assessments have highlighted issues such as vertical cracks and partial disintegration of panels and confining frame elements, significantly impacting the overall seismic behaviour of confined walls [12].

Achieving a reliable bond between a masonry wall and neighboring RC tie-columns can be accomplished through two primary methods: employing ’toothing’ at the interface, where masonry units are staggered at tie-column locations and integrating horizontal reinforcement (dowels) anchored into RC tie-columns. This technique of ’toothing’ at the wall-to-tie-column interface is also referred to as ’shear-key’ or ’toothed shear-key’ in certain research articles [29], [75], and it is commonly recognized in construction and design guidelines [6], [24], [140]. Most research into the connection details between walls and tie columns has focused on the impact of shear connectors or dowels on the in-plane behaviour of confined masonry walls [141], [142]. These studies suggest that reinforcing the interface between the masonry wall and tie column with dowels can enhance the wall’s deformability after reaching its maximum ultimate lateral load. Various connection details, such as dowels and zigzag connections, have been studied for their effectiveness.

Experimental tests by Wijaya et al. [37] compared the performance of CBM walls with different connections, including no anchorage, short anchors (dowels) between each tie-column and the masonry panel, zigzag (toothing) connections, and continuous anchorage along the wall. Results indicated that dowel and zigzag connections are ineffective in enhancing the performance of the tested CBM walls. However, walls with anchoring showed increased load and displacement capacities, although the wall with a zigzag connection exhibited a 16% decrease in load resistance, while a continuous connection allowed for a 3% increase in load capacity.

Similarly, Matošević et al.[38] conducted an experimental study to evaluate the impact of various connection details on the response of CBM walls under lateral cyclic loading, using materials and wall configurations typical of European buildings. The tested walls, measuring 1.44 m in length and 1.65 m in height, are constructed using clay bricks and mortar joints, reinforced with RC ties. Besides the smooth connection, zigzag and dowel connections are also examined. Performance indicators showed that walls with enhanced connections exhibited increased displacement capacity (31% and 79% more for zigzag and dowel connections, respectively) due to diffused cracking and higher inelastic capacity, with slightly lower load resistance (8–10%). The effectiveness of the masonry-to-tie-column connection depends on the materials and wall configuration, necessitating consideration of results from different cases, such as those presented by Singhal and Rai [44].

In addition to these experimental studies, an UNIDO/UNDP [143] study highlighted the advantageous effects of toothed connections on wall performance, shedding light on their potential benefits. Similarly, research by Bartolome et al. [144] compared confined masonry walls with both toothed and dowel connections, revealing enhancements in lateral performance with either connection type. However, earlier literature lacks a definitive recommendation on the preferable type of connection and the criteria for selecting the most suitable connection. There is a need for more comprehensive guidelines that outline the advantages and disadvantages of different connection types, as well as clear criteria for making informed decisions based on specific requirements and contexts.

In this work, we investigate the effect of different types of toothed connections specifically on tie-columns-masonry wall connection details using an extensive finite element investigation. We explore various parameters such as openings, wall thickness, and toothing horizontal and vertical dimensions to ensure the reliability and comprehensiveness of our analysis. Additionally, we evaluate and quantify the influence of these connection schemes on the ultimate strength, stiffness, and energy dissipation capacity of CBM walls. We compare the response of confined wall panels across various connections, including smooth connections at the masonry-concrete interface without tooths, smooth connections with steel dowels in bed joints, and both machine-made and hand-made tooth-type joints. This comparison aims to offer recommendations on connection preference, a novel aspect not explored in prior studies or suggested by confined masonry code books.

6.2 Parametric study

In this section, extensive parametric study have been carried out, delving into diverse facets including various toothing schemes, the influence of wall thickness on these schemes, the impact of openings, and the effect of different tooth sizes on CBM wall performance. Additionally, we assess the seismic responses of CBM walls in relation to these parameters.

6.2.1 Comparison of toothing schemes in CBM walls

The seismic behaviour of a CBM wall panel can be attributed to the monolithic action resulting from the interaction between the masonry wall and the adjacent reinforced concrete (RC) confining elements. A key feature of CBM construction is the presence of toothing between the walls and tie columns, which enhances the composite action between the masonry wall and the RC-tie elements. According to the EERI 2011, there are three recommended methods for providing toothing in confined brick masonry: machine-made, hand-made, and horizontal reinforcement where toothing is not feasible. Additionally, some literature suggests an alternative approach where no toothing is provided [34]. Figure 6.1 illustrates the various toothing methods considered in this parametric study. It is important to note that all walls examined in this study have identical dimensions, materials, and an aspect ratio (h/l) of 1.15.

The seismic behaviour of a CBM wall panel can be explained by the monolithic action resulting from the interaction between the masonry wall and the adjacent reinforced concrete (RC) confining elements. The presence of tooth between the walls and tie columns is a fundamental aspect of CBM construction which facilitates the composite action of masonry wall and the confining RC-tie elements. Figure 6.1 illustrates the various toothing methods used in CBM wall, as mentioned in past literature's [139], used in this parametric study. It is important to note that all the walls having different toothing scheme considered in this study have identical dimensions, materials, and aspect ratio (h/l= 1.15).

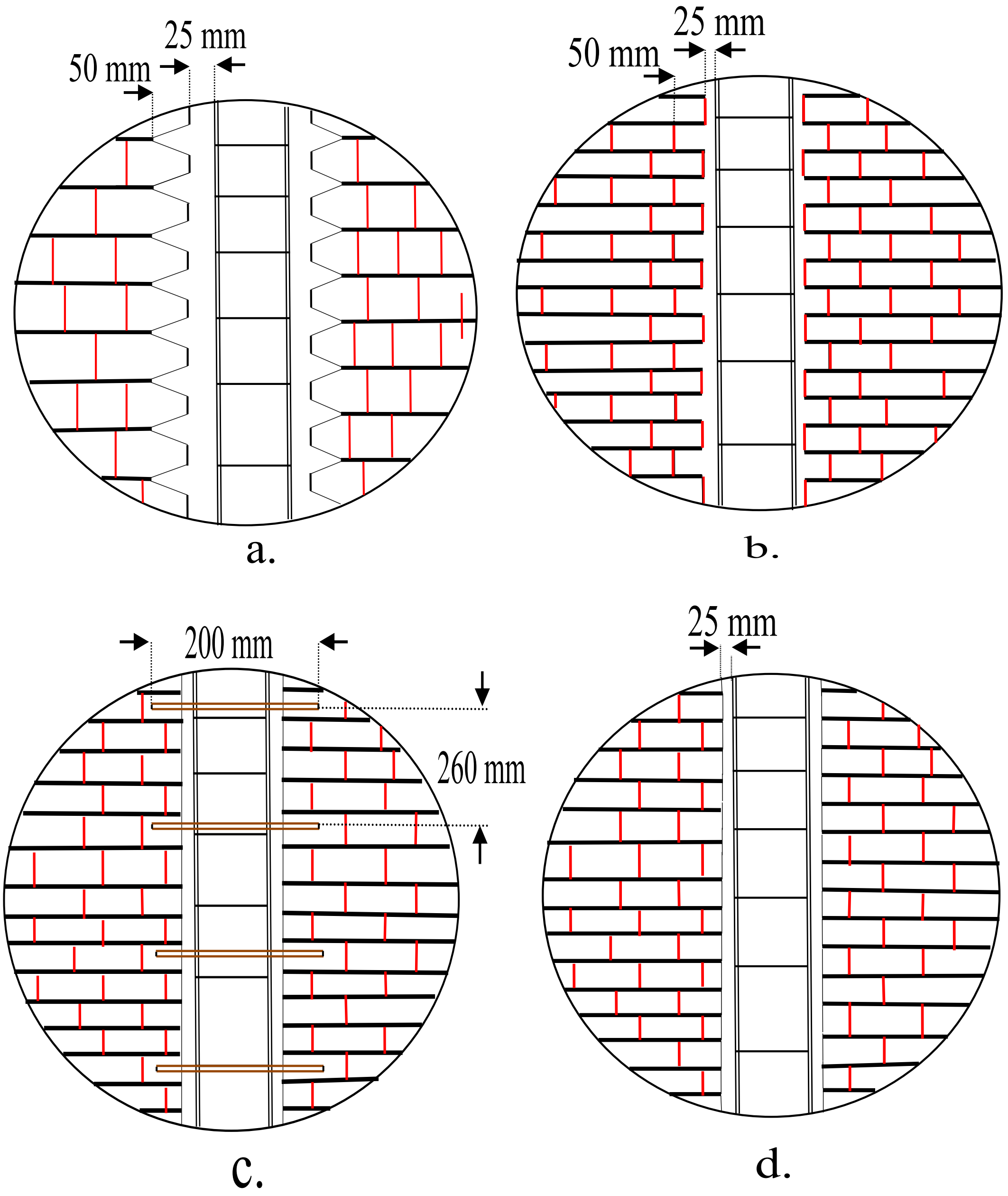


Figure 6.1: Pictorial representation of (a) Hand-made solid units (b) Machine-made hollow units (c) Horizontal reinforcement (d) CBM wall with no-tooth.

Table 6.1: Seismic parameters of the toothing schemes in CBM wall

Toothing Scheme	**Seismic parameters**	
	Ultimate strength (kN)	**Stiffness** (MN/m)
Hand-made unit	237.6	61.3
Machine-made unit	246.4	74.8
Horizontal reinforcement	245.6	62.34
No-tooth	231	59.3

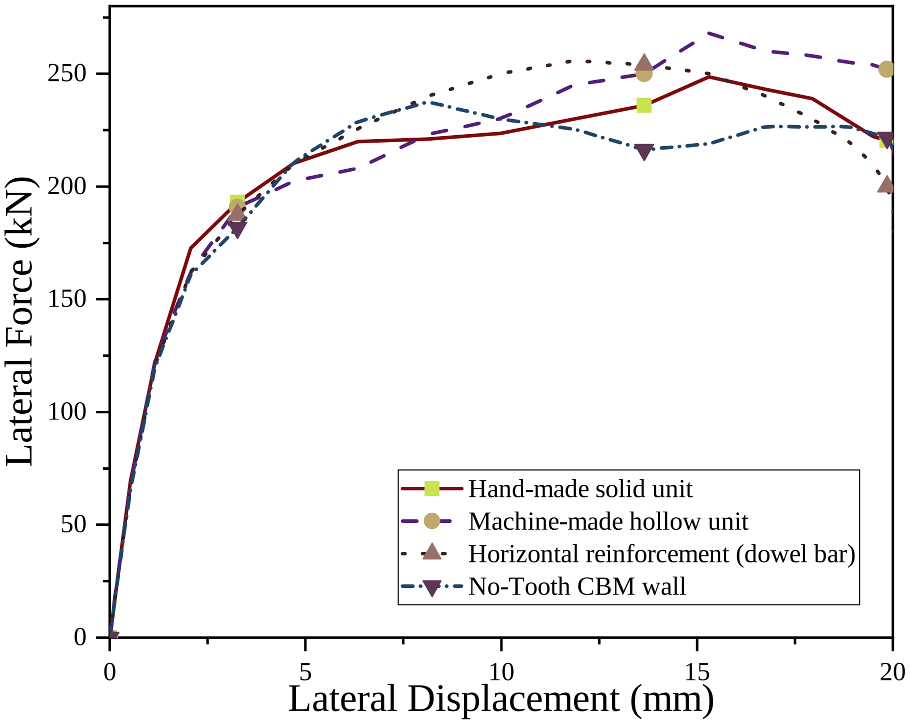


Figure 6.2: Pushover Curves for al the toothing schemes considered in the study

The pushover curves are plotted using a nonlinear finite element analyses, as depicted Figure 6.2. From these curves, the seismic response of the walls is analysed. A summary of the evaluated seismic parameters is provided in Table 6.1. It is observed that the ultimate strength is higher by 3.7%, 0.32%, and 6.6% for machine-made hollow units compared to hand-made units, horizontal reinforcement, and no tooth in CBM walls, respectively. Similarly, the stiffness exhibit significantly higher values for machine-made hollow units compared to other schemes.

Figure 6.3 presents the energy absorption of various toothing schemes in CBM walls. The results indicate that the machine-made hollow toothing scheme in CBM exhibits a higher energy absorption of 1.5%, 15.2%, and 2.8% when compared to the hand-made, horizontal reinforcement, and no-tooth schemes, respectively.

Figure 6.4 depicts the damage progression for various confining schemes in the CBM wall at 20 mm displacement. In the case of the CBM wall with no toothing, the beam-column joint experienced more damage compared to other toothing schemes. This is due to the lack of interlocking between the blocks in the wall, leading to decreased stability and resistance to

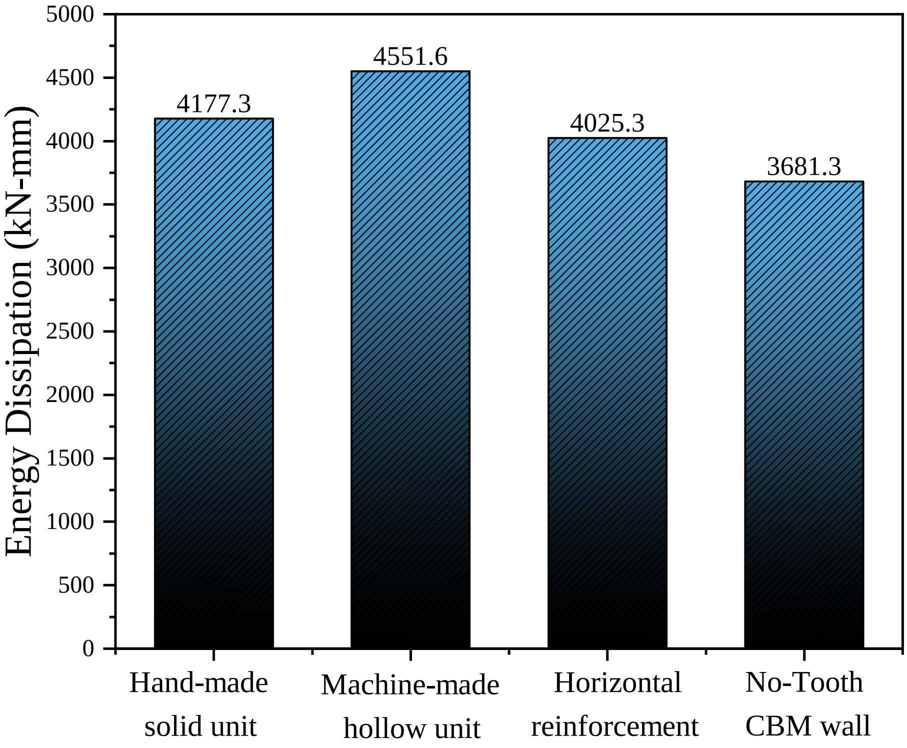
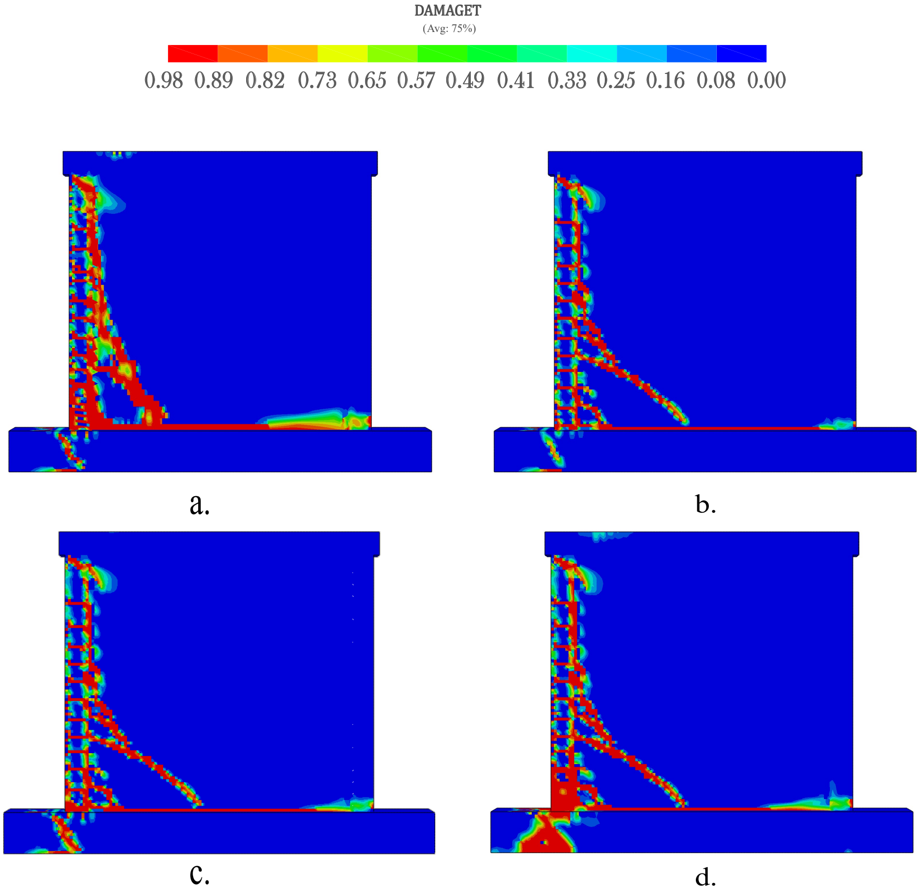


Figure 6.3: Energy dissipation for the toothing schemes considered in this study

Table 6.2: h/t provisions for CBM buildings in different design codes

Code	**Argentina: IN-PRES-CIRSOC 103, Part II (2018)**	**Europe: Eurocode 8, Part1 EN 1998-1:2004 (CEN2004)**	**Peru: E.070 (2006)**	**China: GB 50003-2011 (2011)**	**Chile: NCH 2123.097 (2003)**
Wall h/t (limit)	15	15	20	22 – 26	25

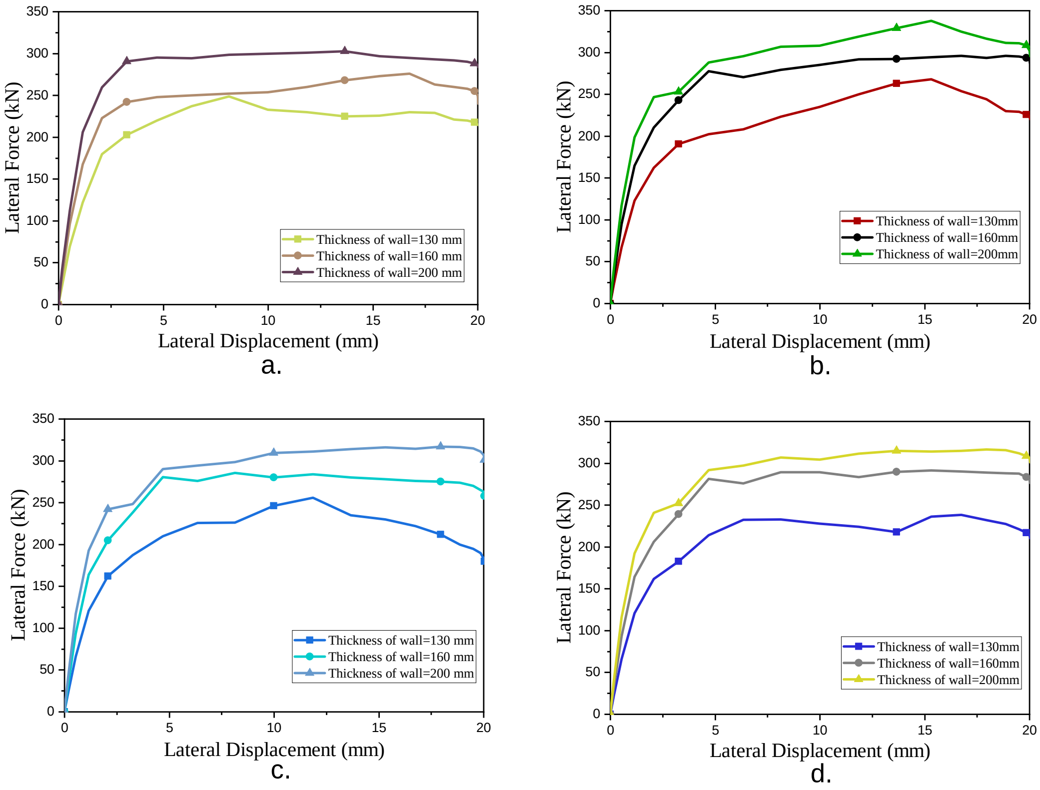
external forces. Without proper interlocking, the load transfer between the beam and column might not be efficiently distributed, resulting in stress concentration at the interface, which could enhance damage. On the other hand, the machine-made toothing scheme showed less damage in the beam-column joint compared to other toothing schemes. Machine-made toothing typically involves precise cutting and shaping of the blocks, ensuring better alignment and interlocking between them. This results in a more robust and stable wall construction, consequently reducing the likelihood of damage to the beam-column joint. Therefore, the observations clearly indicates that the structural performance of the beam-column joint is influenced by the type of toothing scheme employed in the construction of the CBM.



a. b.

c. d.

Figure 6.4: Damage propagation of the toothing schemes a. Hand-made hollow unit, b. Machine-made hollow unit, c. Horizontal reinforcement and d. No-Tooth CBM wall



a.
b.
c.
d.

Figure 6.5: Pushover curve of different toothing schemes for various thickness of the wall (a) Hand-made hollow unit, (b) Machine-made hollow unit, (c) Horizontal reinforcement, (d) No-Tooth CBM wall

6.2.2 Effect of wall thickness on the different toothing schemes

In code of practices, the height to thickness ratio have been defined between the range of 15 to 25, as shown in Table 6.2. This section attempts to analyse the effect of the wall thickness on the various toothing schemes. For this purpose, the thickness of the wall have been varied considering the range of h/t ratios provided by the codes. In this study, wall height is adopted as 3000 mm and thickness is varied between 130, 160 and 200 mm for all the toothing schemes *viz.* hand-made, machine-made, horizontal reinforcement and no-tooth.

Finite element (FE) analyses have been performed on walls with various toothing schemes and thicknesses, resulting in pushover curves depicted in Figure 6.5. Subsequently, these curves are utilised to evaluate the seismic parameters of the wall, as summarised in Table 6.3.

It is observed that as the thickness increases, the ultimate strength and the stiffness value increases for all toothing schemes. Specifically, in the hand-made toothing scheme, the ul-

Table 6.3: Seismic parameters for different h/t ratio for various toothing schemes

Toothing Scheme	**Seismic Parameter**	**h/t Ratio**		
		15	**18.75**	**23**
Hand-made unit	Ultimate strength (kN)	311.2	286.6	237.6
	Stiffness (MN/m)	143.8	110.7	74.4
Machine-made unit	Ultimate strength (kN)	318.9	296.1	246.4
	Stiffness (MN/m)	124.1	89	61.3
Horizontal reinforcement	Ultimate strength (kN)	316.9	295.6	245.6
	Stiffness (MN/m)	132	83.2	59.3
No-tooth	Ultimate strength (kN)	315.9	291.3	238.5
	Stiffness (MN/m)	118.4	86.8	58.8

timate strength and stiffness decreased by 23.6% and 48.2%, respectively, as the h/t ratio increased from 15 to 23. Similarly, for the machine-made, horizontal reinforcement, and no-tooth schemes, the ultimate strength and stiffness decreased by 22.70% and 50.6%, 22.5% and 55%, 24.4% and 50.35%, respectively. Also, by comparing the percentage changes across different toothing schemes, it is observed that although the trend of increasing thickness leading to increased strength and stiffness holds true for all schemes, the rates of change vary as observed from Tables 6.3. For instance it is observed that for the rate of increase in strength is maximum for no-tooth scheme (32.4%) and minimum for horizontal reinforcement scheme (29%). This suggests that the effectiveness of the toothing schemes in enhancing strength and stiffness differs.

6.2.3 Effect of opening in CBM walls with varying toothing schemes

In the realm of building design and construction, openings play a vital role as essential functional elements, facilitating the entry of natural light and fresh air into the structure. Nevertheless, these openings have a notable impact on the structural integrity of masonry wall units, diminishing their torsional resistance and lateral stiffness.

A study has been conducted to compare and enhance the understanding for the influence of openings on CBM walls employing various toothing schemes. This investigation intro-

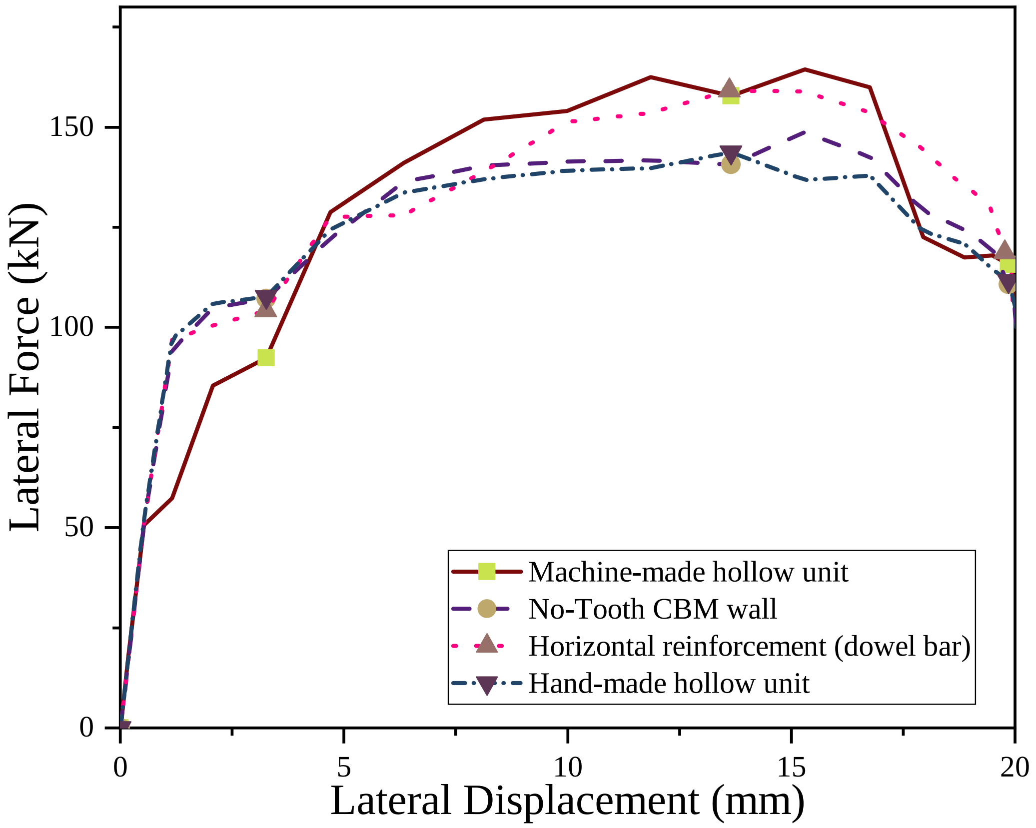


Figure 6.6: Pushover curve of different toothing schemes with opening

Table 6.4: Seismic parameters of opening in CBM walls with different toothing schemes

Toothing Scheme	**Seismic parameters**	
	Ultimate strength (kN)	**Stiffness** (MN/m)
Hand-made unit	143.7	32.9
Machine-made unit	164.5	27.5
Horizontal reinforcement	159.1	28.5
No-tooth	148.7	30.4

duces an opening size equivalent to 10% of the total masonry area. The study incorporates an exhaustive numerical analysis designed to explore the effect of opening on the ultimate strength and stiffness of CBM walls featuring different toothing schemes. Furthermore, the examination encompasses the analysis of pushover curves, as depicted in Figure 6.6. Table 6.4 presents ultimate strength, and stiffness as observed from the pushover curves of opening in CBM walls with different toothing schemes.

It is observed that the hand-made hollow units experience a decrease of 39.50% in ultimate strength and 46.3% in stiffness. Similarly, machine-made hollow units exhibit a reduction of

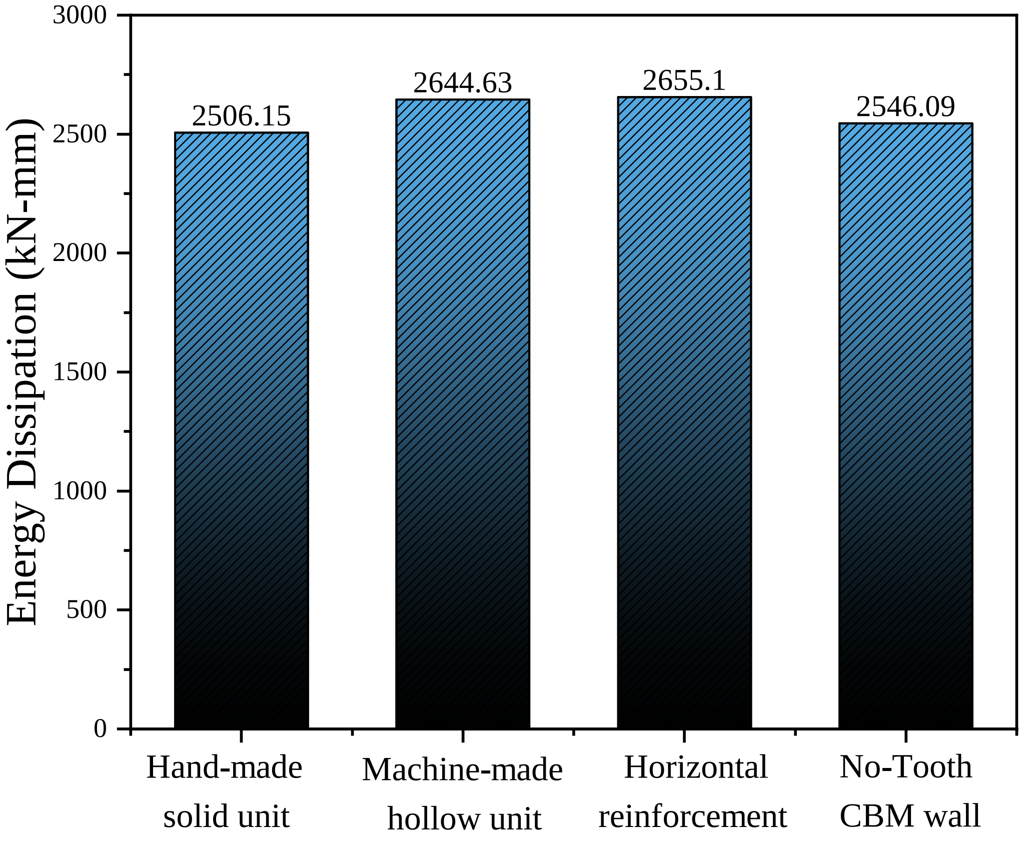


Figure 6.7: Energy absorption for different toothing schemes with opening

33.23% in ultimate strength and 63.23% in stiffness. Moreover, there is a decrease of 35.20% in ultimate strength and 54.30% in stiffness for horizontal reinforcement, and a decrease of 35.60% in ultimate strength and 48.70% in stiffness for CBM walls without teeth. Also, the energy absorption in horizontal reinforcement is higher compared to other toothing scheme as shown in Figure 6.7. The decrease in both the ultimate strength and stiffness in CBM walls is attributed to the presence of openings, which obstruct proper load propagation within the structure. These openings also cause stress concentrations, especially at the corners of the walls, which in turn promote the initiation and propagation of cracks along the diagonal axis, as clearly depicted in Figure 6.8.

Furthermore, it is noted that the configuration and design of tooth profiles have a notable effect on stress concentrations. Varied toothing schemes influence the distribution of forces across contact surfaces, thus modifying stress dispersion. For instance, smoother tooth profiles like those produced by machine-made unit aid in distributing the load evenly, thereby decreasing localised stress concentrations, unlike rough or irregular tooth arrangements typ-

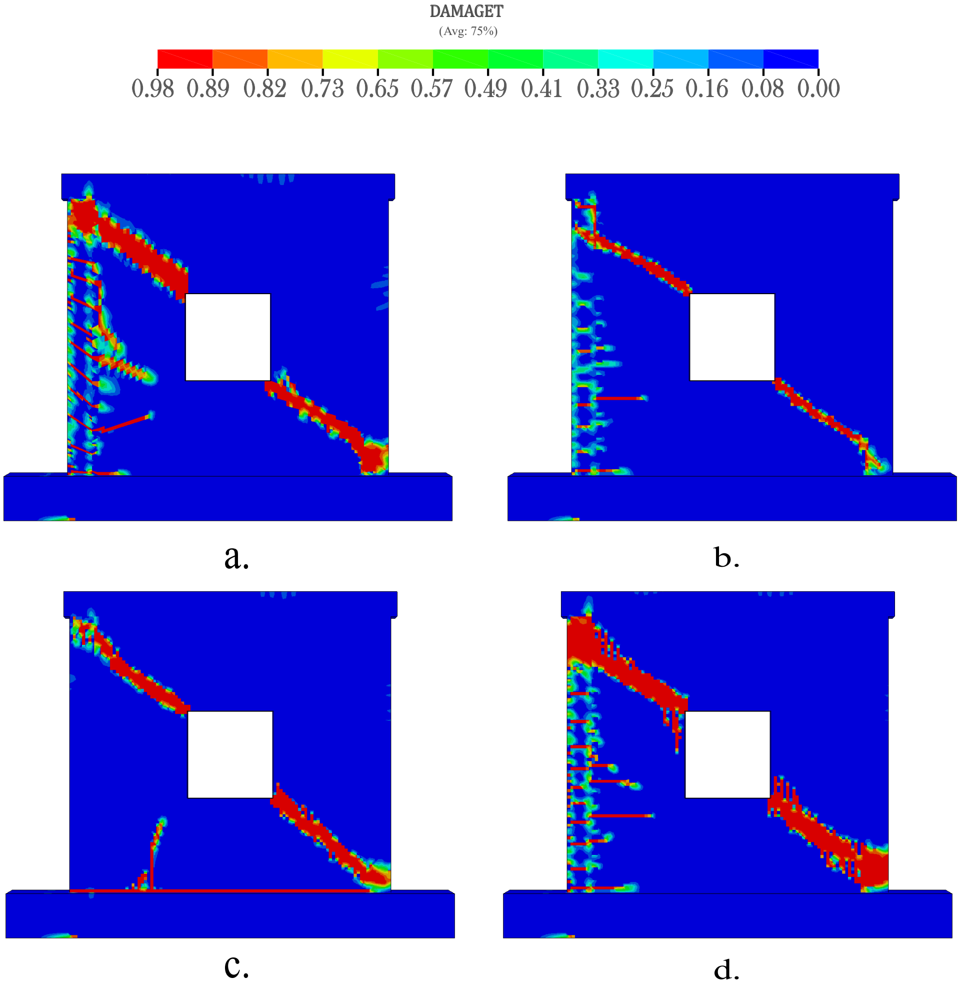
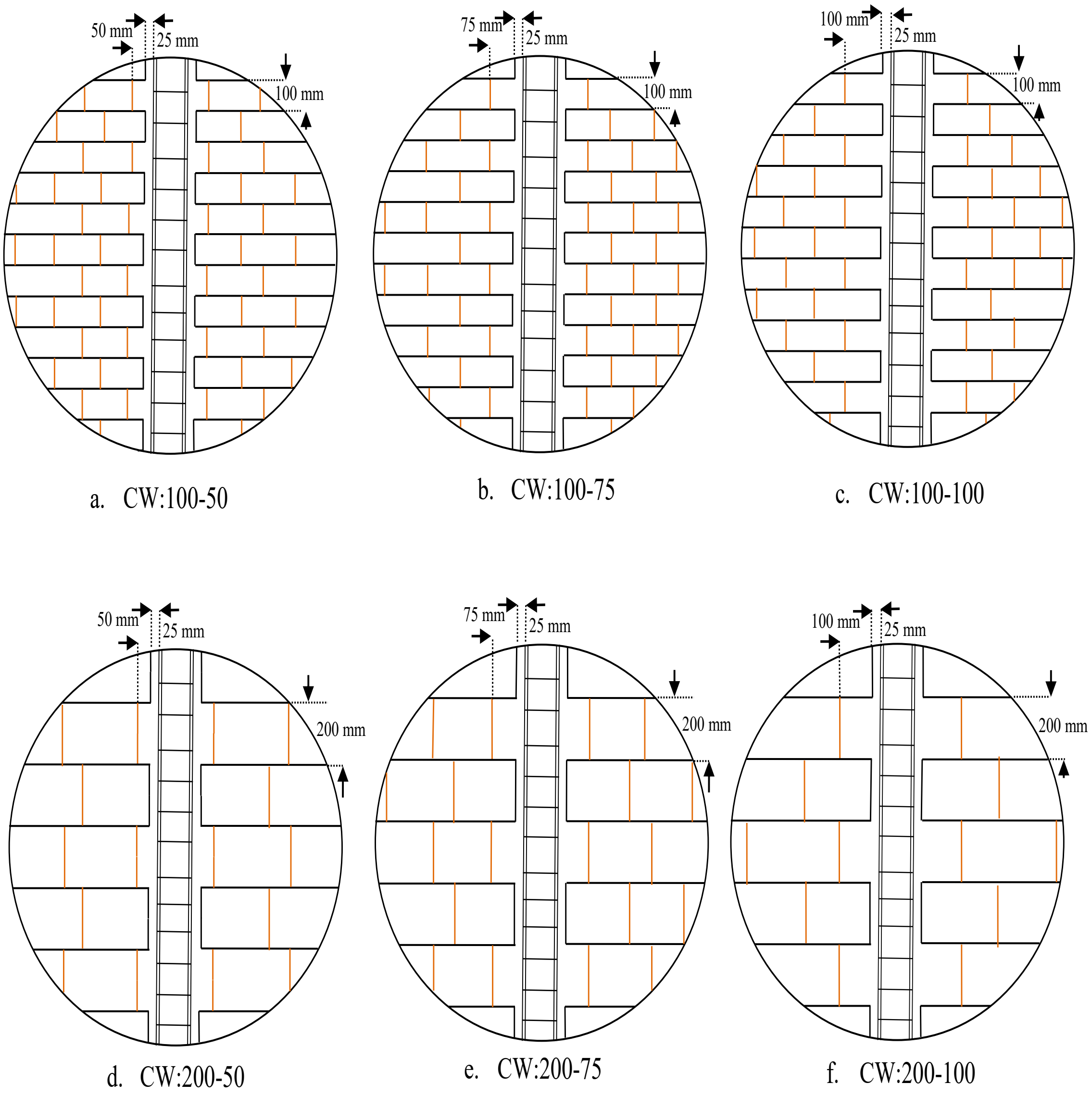


Figure 6.8: Damage propagation for toothing schemes due to opening (a) Hand-made hollow unit, (b) Machine-made hollow unit, (c) Horizontal reinforcement, (d) No-Tooth CBM wall

ical of hand-made unit.

6.2.4 Effect of different tooth sizes in CBM wall

Based on the findings from the previous section, it is observed that machine-made toothing schemes exhibited superior seismic performance compared to dowel bars and hand-made toothing schemes. Singhal and Rai [30] conducted a study focusing on the specific details of toothing, including the optimal vertical and horizontal distances between protruding bricks. They examined three half-scale, two-bay CBM wall specimens with different toothed connections (no toothing, coarse toothing, and fine toothing) under sequential in-plane and out-of-plane loading conditions. The model with fine toothing demonstrated higher ductility and less strength deterioration. In this section, we investigate the effect various tooth size in ma-



a. CW:100-50 b. CW:100-75 c. CW:100-100

d. CW:200-50 e. CW:200-75 f. CW:200-100

Figure 6.9: Pictorial representation of tooth sizes considered in the study

chine made toothing scheme in a CBM wall, as illustrated in Figure 6.9 where, CW represents confined wall, 100 mm and 200 mm is height of vertical projection (VP) and 50 mm, 75 mm, 100 mm is horizontal projection (HP).

Finite element (FE) analyses are conducted, and pushover curves are obtained for individual tooth sizes, as depicted in Figure 6.10, 6.11 and 6.12. The seismic response of the resulting structure is evaluated based on the pushover curves and are presented in Table 6.5. To comprehensively understand the impact of the vertical and horizontal projection of toothing in CBM walls, the study is further divided into two parts: the study of VP and the study of HP.

In the study of horizontal projection, models with a consistent vertical projection of 100 mm

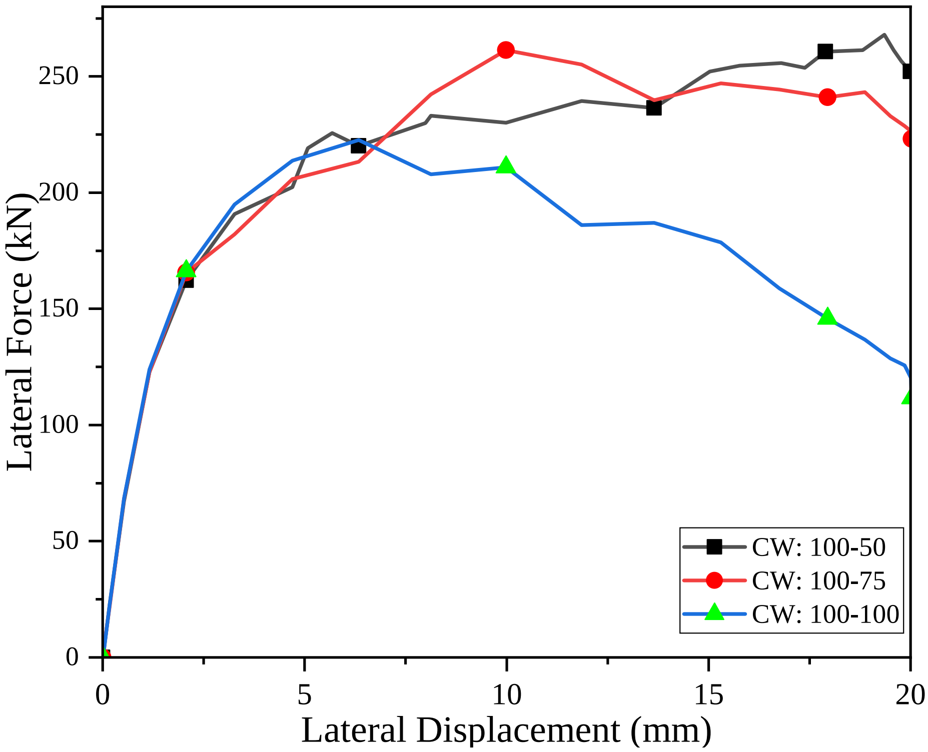


Figure 6.10: Comparing pushover curves for the horizontal projection: VP-100

but varying horizontal projections of 50 mm, 75 mm, and 100 mm are compared. Similarly, models with a vertical projection of 200 mm are compared with horizontal projections of 50 mm, 75 mm, and 100 mm. It is observed that for CW:100-50, the ultimate strength increased by 2.54%, compared to CW:100-75. However, the stiffness decreased by 7.1% in the same case. Additionally, for CW:100-50, the ultimate strength increased by 20.4%, while the stiffness decreased by 44.2% compared to CW:100-100. For CW:200-50, there is a slight increase in ultimate strength by 1.3%, when compared to CW:200-75. However, the stiffness decreased by 2.62%. Furthermore, for CW:200-50, there was an increase in ultimate strength

Table 6.5: Seismic parameters of the different toothing sizes in CBM wall

Tooth size	**Ultimate strength** (kN)	**Stiffness** (MN/m)
100-50	268	44.3
100-75	261.4	47.7
100-100	22.6	79.4
200-50	227.5	67.9
200-75	224.6	69.7
200-100	221.9	75.1

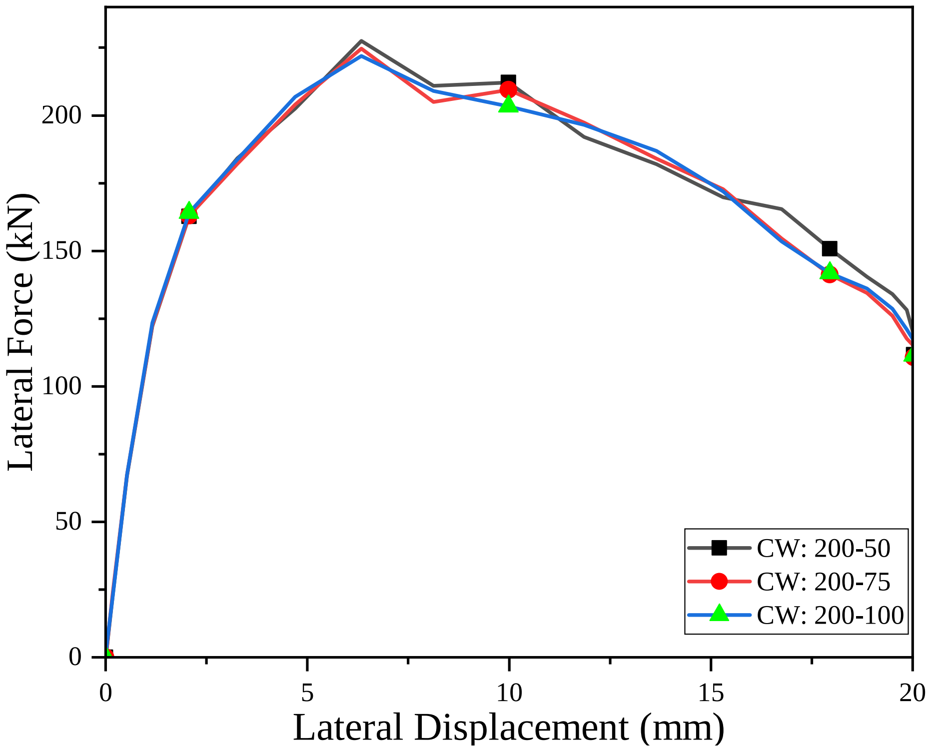
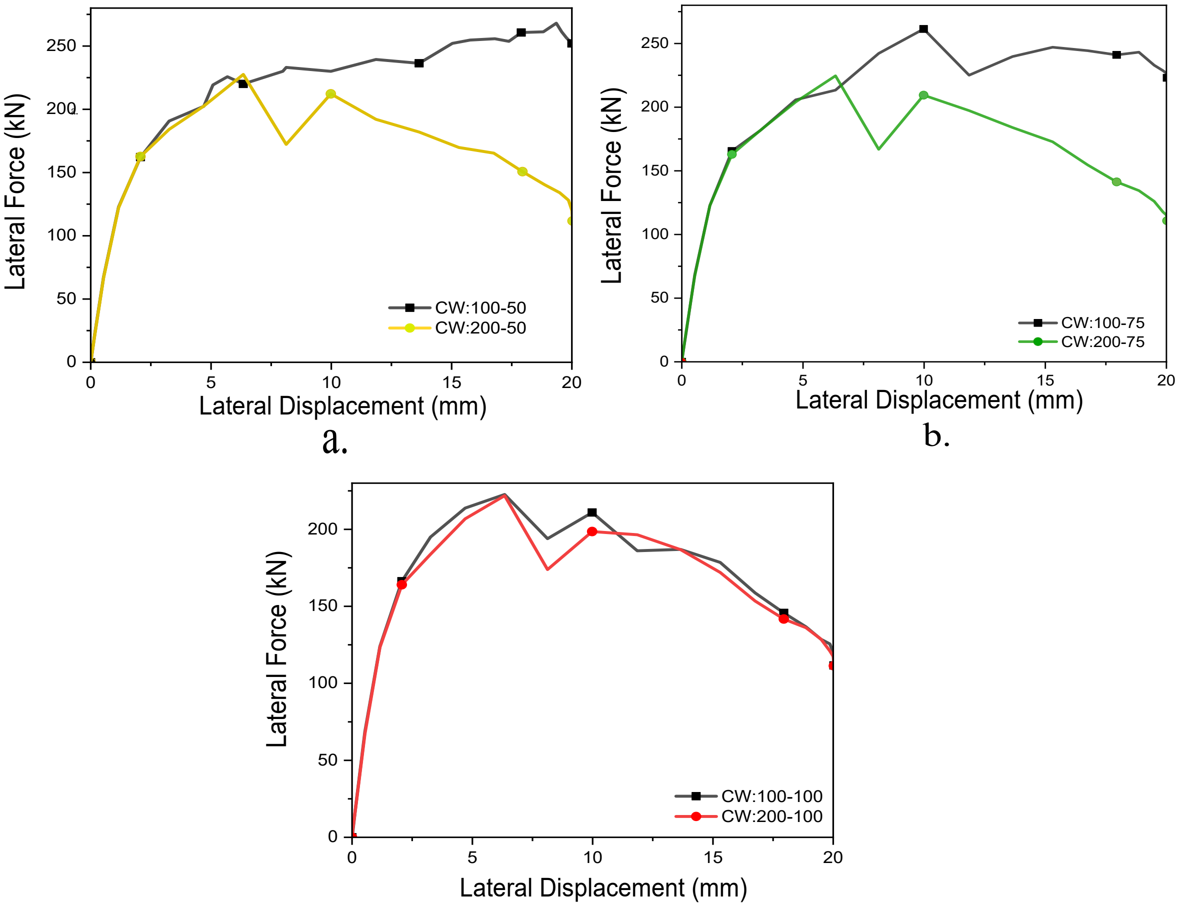


Figure 6.11: Comparing pushover curves for the horizontal projection: VP-200

by 2.55%, compared to CW:200-100. However, the stiffness decreased by 9.56%.

In the study of vertical projection, models with a 100-mm vertical projection are compared to models with a 200-mm vertical projection while maintaining the same horizontal projection. It was observed that for CW:100-50, the ultimate strength increased by 20.9%, compared to CW:200-50. While, the stiffness decreased by 39.6% for the same. For the CW:100-75 model, the ultimate strength increased by 16.34%, compared to the CW:200-75 model. However, the stiffness decreased by 31.57%. For CW:100-100, the ultimate strength increased by 0.33%, compared to CW:200-100. Overall, the results indicate that a 100-mm vertical projection outperforms a 200-mm vertical projection in terms of ultimate strength and stiffness.

In this course of investigation, a crucial aspect involved is the assessment of the maximum tensile damage encountered by the examined walls. The quantification of damage severity was achieved through the implementation of a color scale, wherein a red hue denoted complete damage ($d_t = 0.98$), while a blue hue indicated the absence of damage ($d_t = 0$), as visually illustrated in Figure 6.13. Moreover, an extensive scrutiny was conducted to explore the propagation of damage by comparing the cracks that emerged in CBM using different tooth



a. b.

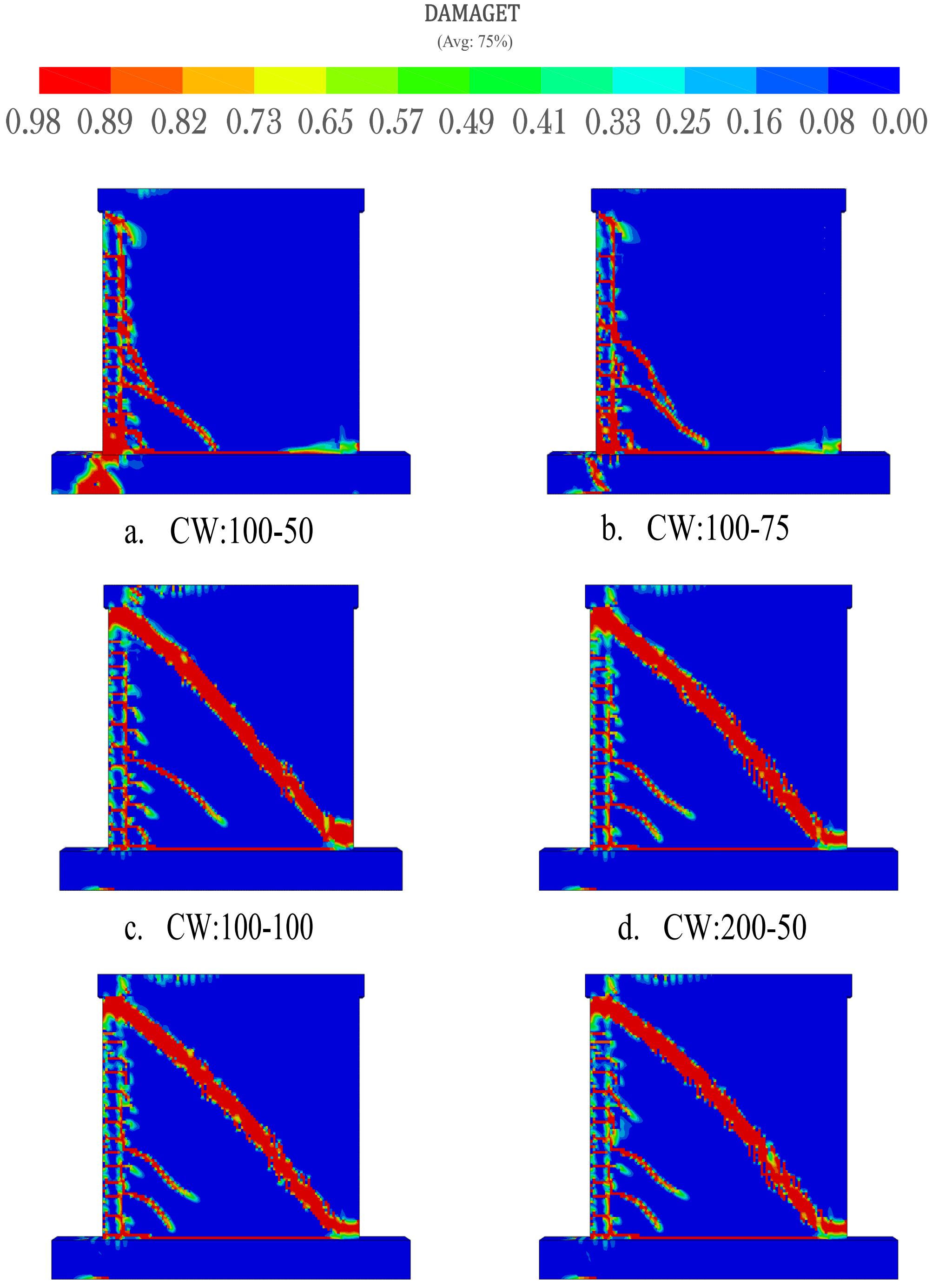
c.

Figure 6.12: Comparing pushover curves for the vertical projections with different horizontal projections a. HP-50, b. HP-75, and c. HP-100

sizes. The primary objective of this analysis is to facilitate a comprehensive understanding of the magnitude and behaviour of damage in these particular types of walls. Notably, it was observed that among all the tooth sizes investigated in this study, CW:100-50 exhibited comparatively less damage in masonry and RC columns. Furthermore, an increase in tooth size corresponded to a higher number of damaged elements in the wall section, accompanied by concrete crushing occurring around the corners.

6.3 Concluding Remarks

This comprehensive parametric investigation delves into the seismic performance of confined brick masonry (CBM) walls, exploring different toothing schemes and its effect on structural and material parameters. Through finite element analyses and rigorous examination, several



a. CW:100-50

b. CW:100-75

c. CW:100-100

d. CW:200-50

e. CW:200-75

f. CW:200-100

Figure 6.13: Damage propagation for different tooth sizes

key findings emerge, shedding light on optimal design considerations for enhancing seismic resilience in CBM wall construction.

Firstly, our study elucidates the significant influence of toothing schemes on seismic behaviour. Machine-made toothing schemes exhibit superior performance compared to handmade and no-tooth schemes, with notable enhancements in ultimate strength, stiffness, and energy absorption. Moreover, variations in tooth size within machine-made toothing reveal considerable effects on seismic parameters, providing valuable insights for practical implementation.

Furthermore, thorough investigations have explored the influence of thickness within CBM walls across various toothing schemes on seismic performance. The findings indicate a correlation between increased thickness and enhanced ultimate strength and stiffness. Particularly, the effectiveness of different toothing schemes in bolstering strength and stiffness varies. Among these, machine-made units have emerged as the most effective, surpassing other schemes in delivering optimal results.

Moreover, an investigation is undertaken to assess how various tooth arrangements within CBM walls, particularly those with openings, impact seismic performance. The results highlight the efficacy of different tooth arrangements in CBM walls with openings varies significantly, with machine-made units emerging as the most effective option compared to other schemes. Additionally, the inclusion of openings has adverse effects on seismic performance due to heightened stress concentrations and hindered load distribution.

The investigation into the vertical and horizontal projections of toothing further refines our understanding, revealing optimal configurations for maximising seismic resilience. Notably, a 100-mm vertical projection outperforms a 200-mm projection in key seismic parameters, highlighting the importance of precise design considerations.

These results emphasize the superior capabilities of the machine-made hollow toothing scheme, suggesting its potential for enhancing the structural resilience and durability of CBM walls. Additionally, this study assesses the severity of damage encountered by CBM walls, providing valuable insights into crack propagation and damage distribution. Larger tooth sizes are found to correlate with increased damage, particularly around corners, indicating the importance of careful design to mitigate structural inability to resist earthquakes.

The findings from this investigation provide valuable practical insights for the construction industry, particularly in seismic-prone regions. By demonstrating the superior performance of machine-made toothing schemes in enhancing the ultimate strength, stiffness, and energy absorption of CBM walls, the study offers clear guidelines for selecting optimal toothing configurations. The insights on the impact of wall thickness, tooth size, and arrangements, especially around openings, enable engineers to design more resilient structures that can better withstand seismic forces. Implementing these recommendations can significantly improve the durability and safety of CBM buildings, ultimately reducing damage and ensuring better protection of life and property during earthquakes.

Chapter 7

Assessment of masonry property and mortar mix on the CBM wall

7.1 General Discussion

The construction of confined brick masonry (CBM) walls involves the use of concrete to confine the masonry, providing necessary confinement, while the masonry walls themselves bear both gravitational and seismic loads. A deep understanding of how different masonry properties affect the performance of CBM walls is essential for ensuring their structural safety and integrity under these loads. However, the current Indian masonry design standard, IS 1905 [145], does not offer specific guidelines for confined masonry construction. To address this gap, the project team employed the Earthquake Engineering Research Institute (EERI) guidelines for designing low-rise confined masonry buildings [139], along with additional references [5], [146]. These resources were adapted to account for the seismicity of the site and the properties of the materials used. The reinforced concrete design followed the specifications outlined in the IS 456 standard [147]. Moreover, this study explores the impact of varying mortar properties on the overall behaviour of the masonry, attempting to gain insights into how changes in masonry materials influence CBM wall performance.

Table 7.1: Types and properties of the bricks

Type	**Density** (Kg/m^3)	f'_{cm} (MPa)	**E** (MPa)	f_y (MPa)
CB(1:1:6)	1764	3.9	975	0.05
CB(1:4)	1764	3.8	950	0.05
FA Set1 (1:1:6)	1614	3.0	1650	0.07
FA Set1 (1:4)	1614	3.6	1980	0.05
FA Set2 (1:1:6)	1498.5	7.6	4180	0.07
FA Set2 (1:4)	1498.5	6.8	3740	0.05

7.2 Parametric study

The use of CBM walls in construction requires concrete to confine the walls, while the masonry walls support both gravitational and seismic loads. Understanding the effect of masonry properties on the performance of CBM walls is crucial for ensuring their structural integrity and safety. To examine this effect, we utilise the masonry properties from a previous study by Jain et al. [148], which analysed two types of masonry units: burnt clay and fly ash (FA). The study divided each type into three sets to determine their mechanical properties, which are presented in Table 7.1. To determine the compressive strength of the masonry, Jain et al. [148] fabricated masonry prisms using two different mortar mix proportions: 1:1:6 (cement: lime: sand) and 1:4 (cement: sand). The prisms are constructed using both burnt clay and FA masonry units. The impact of different masonry properties on the pushover curves have been analysed and is depicted in Fig. 7.1. By using these curves, we calculate the seismic response and tabulated them in Table 7.2. This table shows the variation in the ultimate strength and stiffness parameters for each type of masonry unit and mortar mix proportion.

The results indicate that the CBM wall with FA Set 2 masonry, using a 1:1:6 mortar mix proportion, exhibits 28.24% and 54.50% higher ultimate strength compared to the CBM wall with FA Set 1 and CB masonry, respectively. Similarly, for the 1:4 mix, the CBM wall with FA Set 2 masonry shows 5.6% and 61.20% higher ultimate strength compared to the CBM wall with FA Set 1 and CB masonry. The study also reveals that as the compressive strength of Clay and FA bricks increases, the ultimate strength also increases.

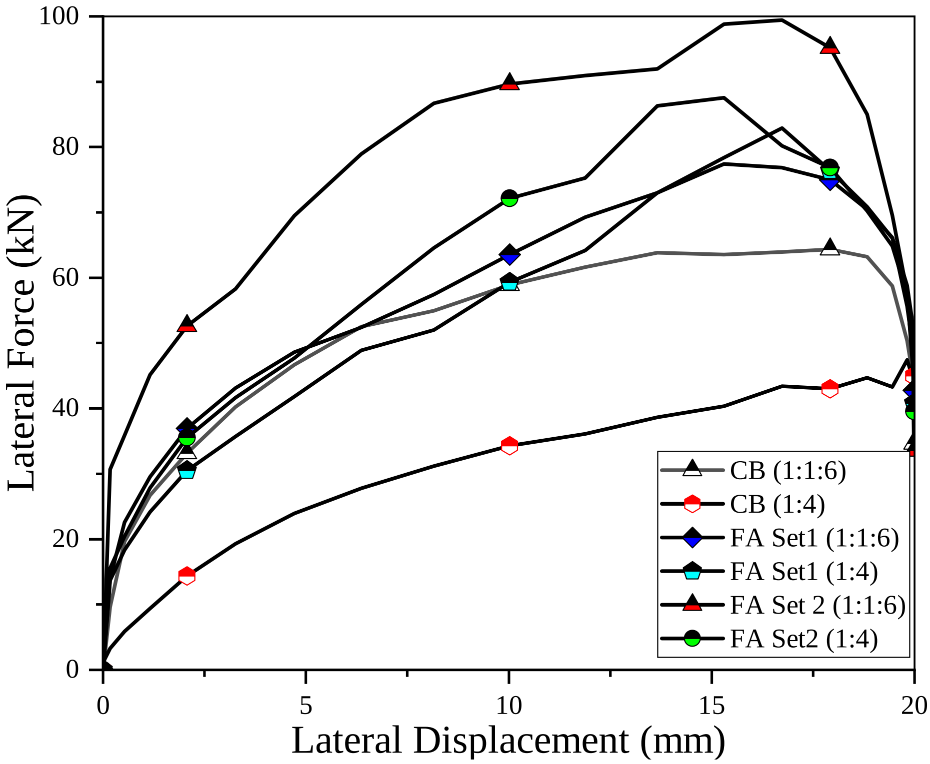


Figure 7.1: Pushover Curves for varying mechanical properties of masonry

Additionally, it is evident that CBM walls constructed using lower compressive strength, FA bricks exhibit higher values of ultimate strength in comparison to the CBM wall constructed with clay bricks. Also, the ductility of the CBM wall increases as the compressive strength increases for all brick specimens except for FA Set 1, where the stiffness decreases as the compressive strength increases compared to the Clay brick and FA Set 2.

Table 7.2: Seismic parameters of the CBM wall with different masonry properties

Type	**Ultimate strength** (kN)	**Stiffness** (MN/m)
CB(1:1:6)	64.35	55.9
CB(1:4)	54.3	37.2
FA Set1(1:1:6)	77.43	83.54
FA Set1(1:4)	82.9	88.4
FA Set2(1:1:6)	99.43	181.20
FA Set2(1:4)	87.55	104.55

7.3 Concluding Remarks

In CBM structures, masonry plays a crucial role as the primary load-bearing component. The mortar mix proportion and masonry compressive strength directly impact the structure's ultimate strength. Increasing the compressive strength of fly ash (FA) and clay bricks results in an expected rise in ultimate strength. However, it is noteworthy that clay bricks with a compressive strength of 3.8 exhibit lower seismic performance compared to FA (Set 1) with a compressive strength of 3. These findings underscore the significance of carefully choosing the masonry type and mortar mix proportions in the design of CBM walls for optimal seismic resistance.